

AN OVERVIEW OF THE EARTH SCIENCE AFTERNOON CONSTELLATION CONTINGENCY PROCEDURES

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The Earth Science Afternoon Constellation comprises NASA missions Aqua, Aura, CloudSat and the Orbiting Carbon Observatory (OCO), the joint NASA/CNES mission CALIPSO and the CNES mission PARASOL. Both NASA and CNES offices are responsible for ensuring that contingency plans or other arrangements exist to cope with contingencies within their respective jurisdictions until the conclusion of all Afternoon Constellation operations. The Mission Operations Working Group, comprised of members from each of the missions, has developed the high-level procedures for maintaining the safety of this constellation. Each contingency situation requires detailed analyses before any decisions are made. This paper describes these procedures, and includes defining what constitutes a contingency situation, the pertinent parameters involved in the contingency analysis and guidelines for the actions required, based on the results of the contingency analyses.

INTRODUCTION

The Earth Science Afternoon Constellation (AC) comprises the National Aeronautics and Space Administration (NASA) missions Aqua, Aura, CloudSat, and the Orbiting Carbon Observatory (OCO), the joint NASA/ Centre National D'Etudes Spatiales (CNES) mission Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), and the CNES mission Polarization and Anisotropy of Reflectances for Atmospheric Science Coupled with Observations from a Lidar (PARASOL). Aqua, Aura and PARASOL are on-orbit while CALIPSO and CloudSat will be launched in late 2005. OCO will be launched in 2008. The AC is required to develop contingency plans and procedures in accordance with NPD 8621.1G NASA Mishap Reporting and Investigating Policy to maintain the safety and health of all members of the constellation. Both NASA and CNES offices are responsible for ensuring that contingency plans or other arrangements exist to cope with AC contingencies within their respective jurisdictions until the conclusion of AC operations.

The Afternoon Constellation, composed of six dissimilar satellites flying in close proximity requires a more complex coordination and examination of contingency scenarios than is normally required for constellation missions. The fact that all six satellites are unique, that their launch dates span years and different launch vehicles increases the complexity of the system as a whole. To ensure the safety and success of these missions, coordination of the flight dynamics activities during mission planning and mission operations is critical. The Earth Science Mission Operations (ESMO) Office at Goddard Space Flight Center (GSFC) has helped to facilitate the coordination of activities between these missions by establishing a Mission Operations Working Group (MOWG) and by developing the Constellation Coordination System (CCS). The AC MOWG coordinates planning and issues relating to the constellation as a whole and has

been the forum for developing the operations concept and contingency procedures for the Afternoon Constellation.

This paper describes these high-level procedures for maintaining the safety of this constellation. It includes defining what constitutes a contingency situation, the pertinent parameters involved in the contingency analysis and guidelines for the actions required, based on the results of the contingency analyses. Contingencies discussed are primarily concerned with avoiding collisions; therefore the key parameters for any action plan are the close approach miss distances and the time remaining before closest approach occurs. Each contingency situation requires detailed analyses before any decisions are made.

BACKGROUND

The AC satellites fly in similar near-circular, sun-synchronous, repeating ground track orbits at approximately 705-km mean equatorial altitude. This configuration allows their instruments to take simultaneous and near-simultaneous measurements of the Earth's surface, oceans, and atmosphere.

Concept of the Control Box

The AC configuration schematic in Figure 1 shows the along-track separation of the satellites in terms of Control Boxes. The Control Box is a theoretical construct centered at some reference position on a satellite's drag-free orbit with dimensions defined by an allowable along-track movement relative to the box's center (the reference position). Underlying the Control Box is the Worldwide Reference System -2 (WRS-2) which establishes the reference ground track. In practice, the along-track movement is coupled with an East-West movement of the satellite's ground-track relative to the idealized ground-track of the drag-free orbit. It is this limitation in both the along-track and cross-track movements that creates the notion of a two-dimensional "box".

The Control Box construct was established originally to address science requirements, that is, to maintain optimal spacing of satellites to maximize science returns without requiring a great deal of active coordination between satellite operations Control Centers. If a satellite stays within its own Control Box, it should never create a collision risk to any other satellite. The Control Box can be used to provide an "early warning" if a satellite leaves its designated area and potentially threatens another satellite.

As can be seen in Figure 1, the Aqua, CALIPSO, and PARASOL all maintain Control Boxes that are ± 10 kilometers measured along the equator at the descending node (corresponding to ± 21.5 seconds in equator crossing time), while Aura's Control Box is ± 20 kilometers measured along the equator at the descending node (corresponding to ± 43 seconds in equator crossing time). OCO plans to maintain a much larger Control Box, ± 107.5 seconds at the front of the constellation. CloudSat represents a special case in that it will fly in formation with CALIPSO at a spacing of 12.5 ± 2.5 seconds in the direction of Aqua. Even though OCO will be flying at the front of the AC, Aqua is

considered the lead satellite of the AC, since all AC missions fly in constellation with Aqua.

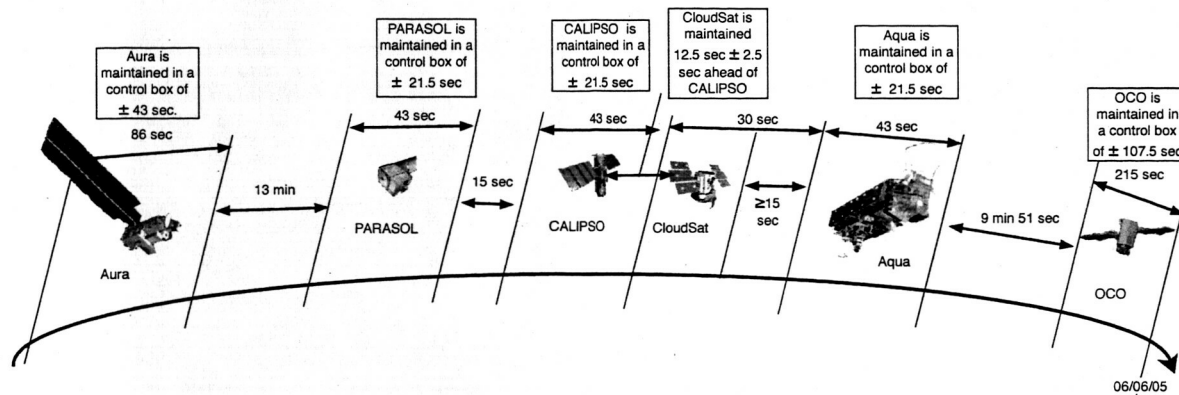


Figure 1 – Baseline Afternoon Constellation Orbit Configuration

Satellites will move in a predictable fashion within their Control Boxes (Figure 2). This motion is called a circulation orbit and represents the relative motion of each satellite to its Control Box. At its mean semi-major axis (SMA) altitude, the satellite traces the correct ground track. Aerodynamic drag slows the satellite, dropping its altitude, thereby making the satellite speed up relative to its "fixed" Control Box. Eventually, the satellite needs to perform an orbit-raising maneuver in order to stay within its box. This moves the satellite above its mean SMA altitude, so that it is slower than the Control Box. Drag takes over, forcing the satellite to lower its orbit and then the cycle repeats.

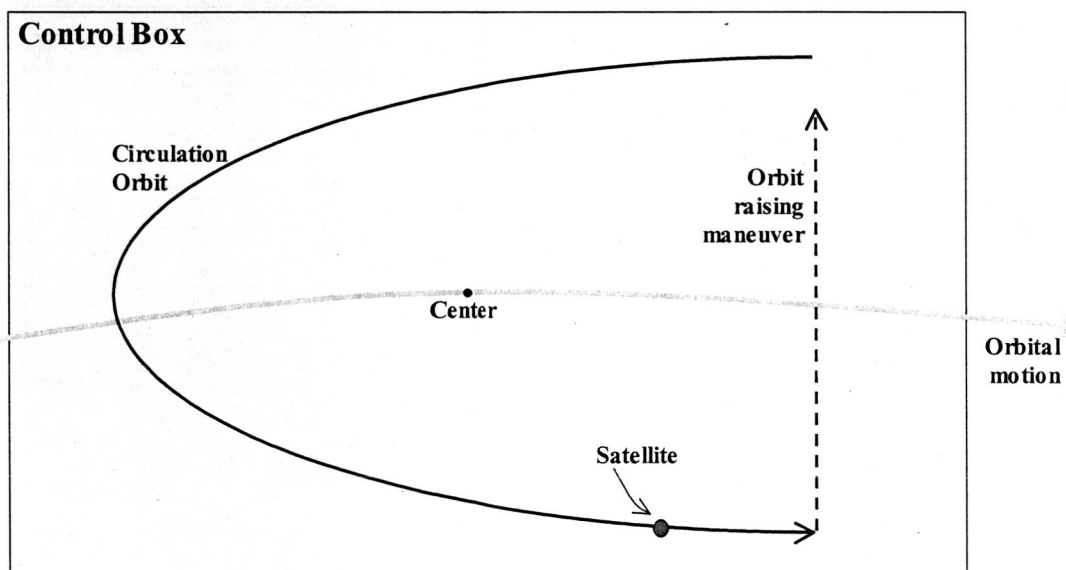


Figure 2 – Control Box / Circulation Orbit Relationship

Figure 3 shows the special case of CloudSat flying in formation with CALIPSO. Though there is a 30-second buffer between the CALIPSO and Aqua Control Boxes, the

CloudSat satellite can be as close as 15 seconds to the trailing edge of Aqua's Control Box.

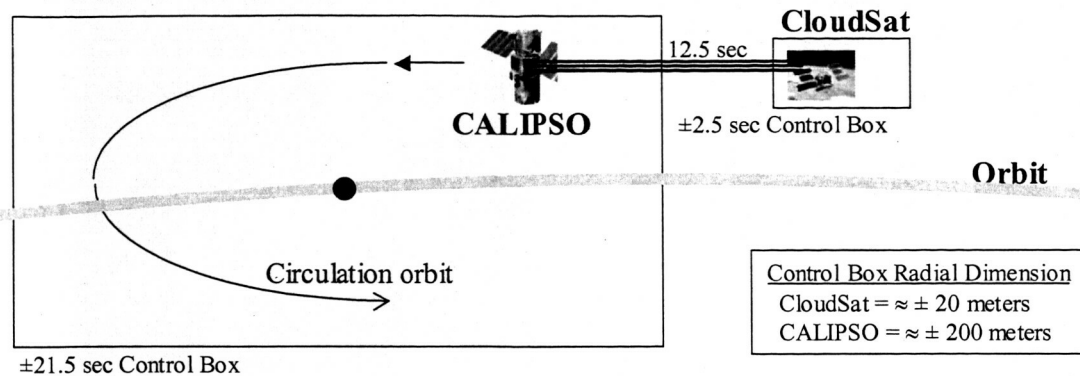


Figure 3 – CloudSat/CALIPSO Formation Flying

The Zone of Exclusion Concept

The AC Zone of Exclusion (ZOE) shown in Figure 4 is defined as a rectangular region in a satellite radial, in-track, cross-track (RIC) coordinate system centered on each of the AC satellites.

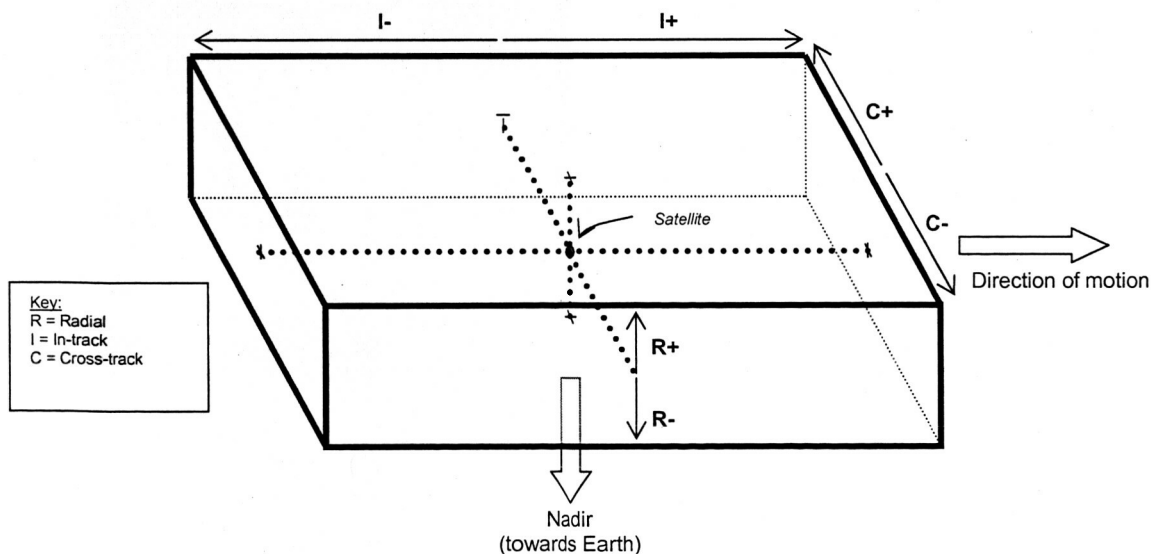


Figure 4 – Zone of Exclusion

For the AC, two ZOE's have been defined as shown in Figure 5: the Alert ZOE and the Action ZOE. The dimensions of each ZOE are shown in Table 1. These dimensions are based on parameters used for the International Space Station for debris avoidance, not through a specific study of possible values for the AC.

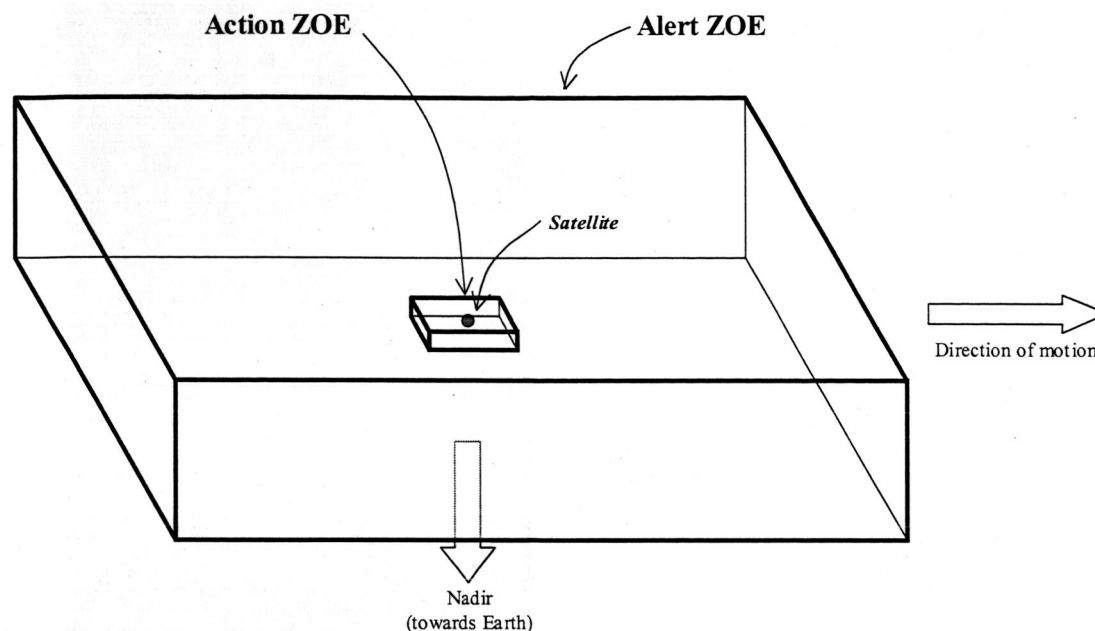


Figure 5 –ZOE Relationships

Table 1 –Zone of Exclusion Dimensions

ZOE	Radial (km)	In-Track (km)	Cross-track (km)
Alert ZOE	2.0	25.0	25.0
Action ZOE	0.5	5.0	5.0

This 2-tier ZOE structure reflects the difference in concern in the two volumes. For example, a satellite that is just inside the Alert ZOE does not present an immediate danger, whereas a satellite that enters an Action ZOE is cause for action.

- The Alert ZOE is used to provide notifications to affected missions of a potential close approach. Predicted entry into this region is cause for concern, but not necessarily immediate reaction. The Alert ZOE defines a "keep-out" or "no-go" zone for other satellites. A close approach between two Constellation satellites inside a

ZOE may be considered unsafe by representing an unacceptable level of risk of collision. Orbit prediction tools used by the AC are accurate enough, even including uncertainties, that if the Alert ZOEs are honored during maneuver design there is no chance of collision with another satellite.

- An Action ZOE violation signifies an unacceptably high risk of a collision and is to be avoided, if possible, by use of an evasive maneuver. If an Action ZOE violation is predicted to occur, the functioning satellite is required to take immediate action. When a functioning satellite maneuvers in order to pass above (or below) another satellite in the Constellation it shall do so in a manner such that neither satellite's Action ZOE is violated (taking into account 3 sigma errors in orbit determination and maneuver execution).

The Constellation Coordination System

The NASA Earth Science Mission Operations office has developed the Constellation Coordination System (CCS) to assist in the critical coordination of flight dynamics activities during mission planning and mission operations and AC contingency situations. The CCS is a collection of tools that enables flight dynamics data exchange and facilitates communications among the Control Centers of the missions of the Afternoon Constellation. The main capabilities of the CCS include acquisition and delivery of mission data products, access to tools for on-line flight dynamics analysis, performing automatic analyses for constellation health and safety monitoring, and notification of constellation status changes. The CCS functions performed in the context of AC contingencies will be described below.

Contingency Situations in the Context of the Afternoon Constellation

A contingency situation is defined as any mission-related failure, mishap or incident (involving flight or test hardware, support equipment, or facilities) that significantly delays or jeopardizes a mission, or prevents accomplishment of a major scientific objective. An anomaly is an unplanned deviation from normal spacecraft operations, such as a satellite entering safehold and being unable to control its orbit. Loss of orbit control is a serious anomaly because the satellite can not control its position within the Constellation. The Flight Operations Team (FOT) will restore the spacecraft as quickly as possible to its normal operating state, but the severity of the anomaly may cause a long delay.

The MOWG has defined a credible AC contingency situation as a circumstance or condition within the constellation whereby a spacecraft is in a safe-hold condition and has drifted outside of its Control Box. This contingency situation is "contingent" on a prolonged safe-hold having occurred and can escalate in severity to the point of a potential collision between member satellites. With uncorrected drifting, eventually one satellite can make an unplanned close approach to another unless an evasive maneuver is performed. Such a contingency requires a coordinated action plan be

established before the event, with actions defined and agreed upon beforehand for both affected satellites.

Most, but not all of the identified contingency situations described below involve one functioning satellite being threatened by a non-functioning satellite, so it is useful to provide an overview of this generic situation before getting into more specific scenarios. In this context, a *functioning* satellite has the propulsive capability to change its orbit, while a *non-functioning* satellite (i.e., in safe-hold) does not.

AC CONTINGENCY PROCEDURE OVERVIEW

The MOWG has defined a generic approach to contingency situations which can be extended to all scenarios examined, including those not involving potential collisions. Execution of a contingency procedure may go through several stages, with each successive stage representing an escalation in the contingency:

- Monitoring and Detection
- Analysis
- Notification and Coordination
- Maneuvers

Monitoring and Detection

Monitoring is performed through two primary methods:

- Each Control Center monitors the position of its satellite.
- Each Control Center provides ephemerides on a daily basis to the CCS tool. At the receipt of the ephemeris files, CCS automatically performs its analyses of orbital positions of all satellites.

Using the position data, both the Control Center and the CCS determine:

- Is the satellite still in its Control Box?
- Will it remain in its Control Box for the span of the predictive ephemeris?

Analysis

If any satellite has left (or is predicted to leave) its Control Box, the CCS will automatically perform additional analyses to determine the likelihood that the satellite will endanger any other.

The results of these analyses will include the following:

- When did/will the satellite leave its Control Box?
- Will the satellite enter the Control Box of another satellite and if so, when?

- Will the satellite enter the ZOE of another satellite and if so, when?
- What will be the "miss distance" at closest approach?

Notification and Coordination

Coordination starts with the satellite operations teams in each Control Center. Clearly, each Control Center will be fully aware of an impending contingency situation caused by its own satellite. One of the main purposes of the CCS is to supplement this by alerting a team via e-mail that its satellite may be threatened by the approach of another satellite. This notification also is emailed to the NASA Constellation Manager (CM). Regardless of how a potential contingency is detected, the notification to the affected Control Centers is handled in the following manner. If a Control Center becomes aware of a potential contingency situation, whether through its own analysis or through the analysis of the CCS, it notifies the affected Control Center(s) directly through e-mail and/or telephone. Notification is provided at the same time to the NASA CM. Depending on the criticality of the contingency, the satellite's team will set various status flags within CCS to provide notification to the CCS user community.

The affected teams will coordinate their actions in accordance with the AC Operations Coordination Plan (ACOCP) procedures. The Control Centers maintain communication throughout the period of contingency and corrective measures with each other and the NASA CM.

Maneuvers

First and foremost, the goal of this coordination shall be to return each satellite to its Control Box. The satellite that left (or will leave) its Control Box has the prime responsibility to make correctional maneuvers and return to its Control Box.

If this is not possible, steps shall be taken by the other satellites to ensure that potential close approaches and/or collisions are avoided at all costs. If the drifting satellite has no orbital control, the responsibility for self-preservation falls upon the threatened satellite(s). The threatened satellite(s) shall execute evasive maneuvers to prevent unacceptably close approaches with any other satellite.

If any of these maneuvers cause additional satellites to leave their Control Boxes, an action plan shall be identified to either return all functioning satellites to their Control Boxes once the danger has passed, or if necessary, seek approval to change the AC configuration. A configuration change is not to be approached lightly since this may cause additional science and operational concerns. The MOWG is the governing body in such decisions.

Most potential contingency situations involve one satellite lacking orbital control, call it Satellite B (think "Broken") that is approaching a functioning satellite, call this one Satellite A (think "A-OK") (see Figure 6). If Satellite B remains without orbital control, it

will drift and may eventually threaten Satellite A. Satellite A may need to make maneuvers to avoid Satellite B. Debris from a collision could pose a risk for the entire Constellation.

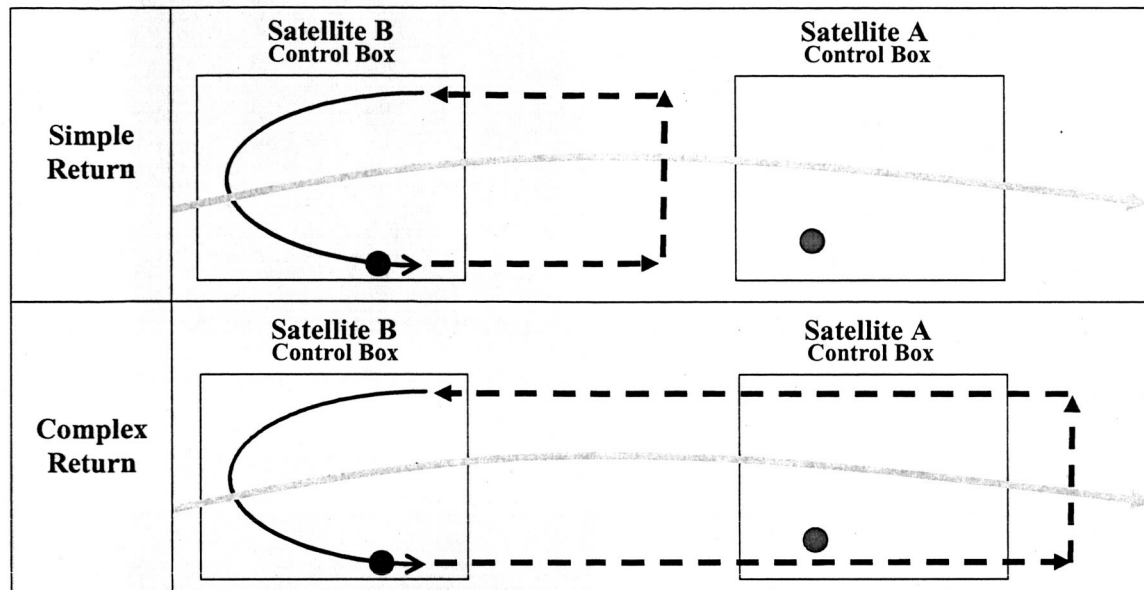


Figure 6 – Collision Avoidance Scenario with Satellite A and Satellite B

AFTERNOON CONSTELLATION CONTINGENCY SCENARIOS

Several specific contingency scenarios have been identified for the AC. Analysis of each specific contingency situation is critical to establish a timeline when actions (e.g., evasive maneuvers) must be performed. Each of the identified scenarios is discussed below.

Aqua in a Prolonged Safe-Hold

Aqua is located at the “front” of the AC (until the launch of OCO). A prolonged safe-hold which prevents orbit maneuvering will cause it to drift forward, as shown in Figure 7. Because it will move away from the rest of the Constellation it will not pose a threat to any satellite other than OCO. This threat to OCO is minimal due to the large separation of the two satellites. It will take several weeks for Aqua to drift to the vicinity of OCO, allowing plenty of time to react using the standard collision avoidance procedure described above, with Aqua as Satellite B and OCO as Satellite A.

A separate issue for the Constellation will be the loss of the Aqua satellite and instruments for science coordination. Also, the role of Constellation “lead” will need to be reassigned.

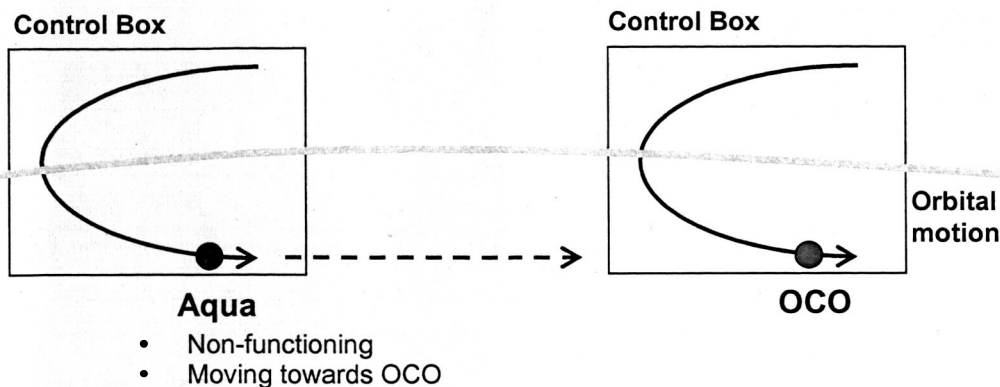


Figure 7 – Collision Avoidance Scenario between Aqua and OCO

CloudSat in a Prolonged Safe-Hold

If CloudSat remains in a prolonged safe-hold, it will drift and eventually may enter CALIPSO's Alert ZOE (see Figure 8).

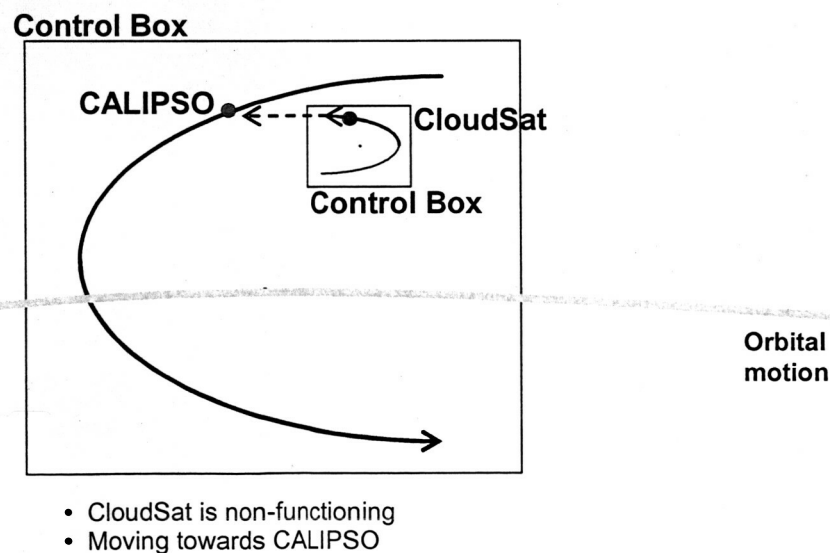


Figure 8 – Collision Avoidance Scenario between CloudSat and CALIPSO

CloudSat nominally moves along its circulation orbit in 13 to 50 days (depending on the level of atmospheric drag). As such, the "worst-case" scenarios addressed below may be favorably biased by up to 13-50 days, depending on where in the circulation orbit the safe-hold occurs. The close approach may or may not be considered threatening, depending on the distance between the satellites.

Under the highest recorded atmospheric drag while at the worst location:

- CloudSat will enter CALIPSO's Alert ZOE in about 5 days
- A CloudSat close approach with CALIPSO will occur in about 7 days.

Under typical atmospheric drag while at the worst location:

- CloudSat will enter CALIPSO's Alert ZOE in about 11 days
- A CloudSat close approach with CALIPSO will occur in about 17 days.

The standard collision avoidance procedure will be followed to ensure that there is no unacceptable close approach between CloudSat (as Satellite B) and CALIPSO (as Satellite A).

PARASOL in a Prolonged Safe-Hold

If PARASOL remains in a prolonged safe-hold, it will drift and may eventually enter CALIPSO's Alert ZOE (see Figure 9).

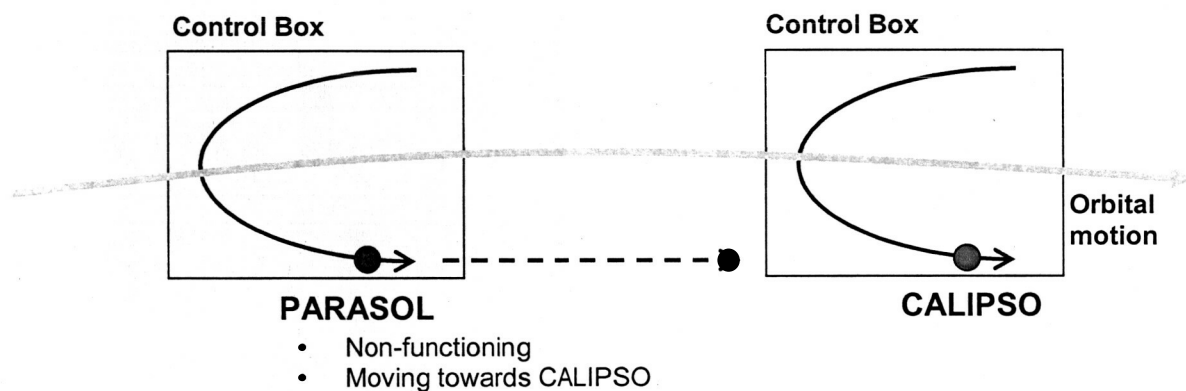


Figure 9 – Collision Avoidance Scenario between PARASOL and CALIPSO

Several days or weeks are expected to elapse before PARASOL drifts sufficiently to threaten CALIPSO. The standard collision avoidance procedure will be followed to ensure that there is no unacceptable close approach between PARASOL (as Satellite B) and CALIPSO (as Satellite A).

Aura in a Prolonged Safe-Hold

If Aura remains in a prolonged safe-hold, it will drift and may eventually enter PARASOL's Alert ZOE (see Figure 10).

If Aura begins to drift, it will move closer to the PARASOL satellite. It will take several weeks for Aura to drift to the vicinity of PARASOL, allowing plenty of time to react using the standard collision avoidance procedure.

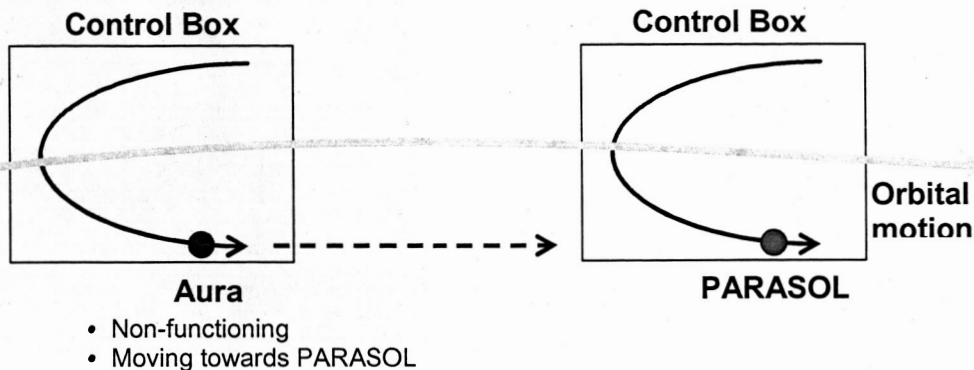


Figure 10 – Collision Avoidance Scenario between Aura and PARASOL

OCO in a Prolonged Safe-Hold

If OCO remains in a prolonged safe-hold, it will drift and eventually leave the AC (see Figure 11).

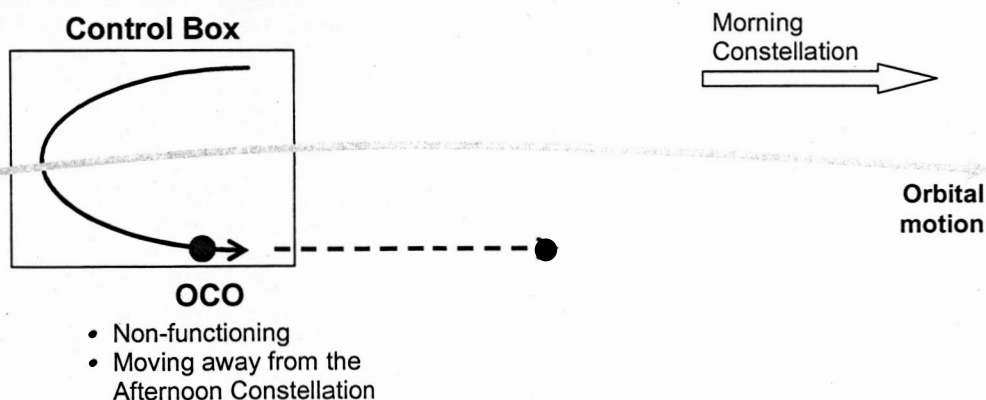


Figure 11 – Collision Avoidance Scenario Involving OCO

Since OCO will be a large distance in front of the rest of the Constellation, it should pose no immediate danger if it loses orbital control. Close approach analysis with the Earth Science Morning Constellation shall be performed to minimize the slight risk of OCO drifting within allowable Morning Constellation satellite ZOE's.

CALIPSO in A Prolonged Safe-Hold

If CALIPSO remains in a prolonged safe-hold and has lost orbital control, it will drift and eventually enter Aqua's Alert ZOE. This scenario differs from the earlier ones in that if the formation is maintained, this drifting motion will force CloudSat into Aqua's Alert ZOE as well (see Figure 12).

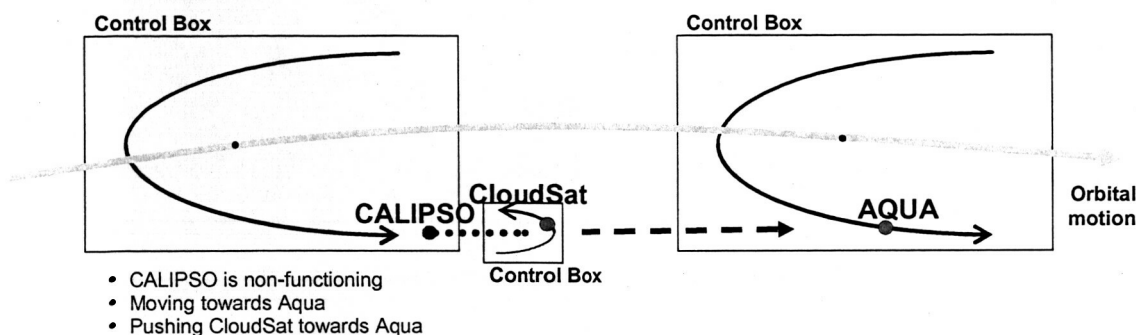


Figure 12 – CALIPSO in Prolonged Safe-Hold

CALIPSO nominally moves along its circulation orbit in 35 to 130 days (depending on the level of atmospheric drag). As such, the “worst-case” scenarios addressed below may be favorably biased by up to 35-130 days, depending on *where* in the circulation orbit the safe-hold occurs.

A second variable is the location of Aqua during this safe-hold. This can greatly influence whether/when a close approach will occur.

A final complication is the position of CloudSat. If CloudSat maintains its formation with a CALIPSO in safe-hold, it will be forced into Aqua's Control Box and Alert ZOE. Under these circumstances, CloudSat is allowed to enter Aqua's Control Box, but is to maneuver (a) before it enters Aqua's Alert ZOE and (b) at least 4 days before closest approach with Aqua, whichever comes first.

Under the highest recorded atmospheric drag while at the worst locations and if no actions are taken:

- CALIPSO will leave its Control Box in 0.4 days
- CloudSat will be forced into Aqua's Control Box in 3.3 days
- CALIPSO will enter Aqua's Control Box in 6 days
- A CALIPSO close approach with Aqua will occur in about 9 days.

Under typical atmospheric drag while at the worst location and if no actions are taken:

- CALIPSO will leave its Control Box in 1 day
- CloudSat will be forced into Aqua's Control Box in 11 days
- CALIPSO will enter Aqua's Control Box in 14 days
- A CALIPSO close approach with Aqua will occur in about 21 days

Drag Makeup Maneuver Too Large - Missions Having Retrograde Capability (Applicable to CloudSat, CALIPSO, PARASOL, and OCO)

If a satellite executes an orbit-raising maneuver that exceeds its target to the extent that the satellite will leave its Control Box and places another constellation satellite at risk, a corrective maneuver will be required for missions that have retrograde maneuver capability (see Figure 13).

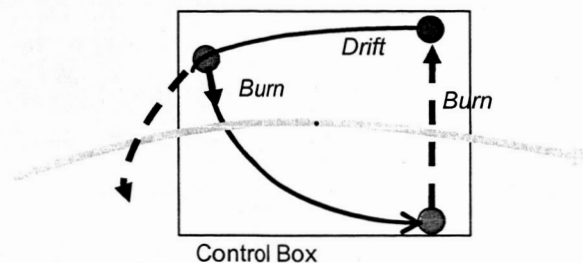


Figure 13 – Drag Makeup Maneuver Too Large
(Retrograde maneuver capability available)

It is desirable for the satellite to correct its orbital position early by performing a retrograde burn, before it can stray near any other satellites in the Constellation. The urgency of a retrograde maneuver will depend on the magnitude of the over-burn.

Drag Makeup Maneuver Too Large - Missions without Retrograde Capability (Applies to Aqua and Aura)

If a satellite executes an orbit-raising maneuver that exceeds its target to the extent that the satellite will leave its Control Box, a corrective maneuver would be desired, but will not be possible for missions lacking retrograde maneuver capability, i.e., Aqua and Aura (see Figure 14).

Since no retrograde maneuver capability exists for Aqua or Aura, they will be forced to wait until their semi-major axis has decreased from the effects of drag before they can execute a corrective orbit-raising maneuver. Depending on the extent of the over burn, this could place other satellites in jeopardy. The contingency situation could escalate into a standard Satellite A/Satellite B collision avoidance scenario, except that both satellites retain propulsive capability. The prime responsibility to rectify this situation rests with the satellite that performed the over burn (i.e., Satellite B), but other satellites may offer to perform evasive maneuvers, at their discretion.

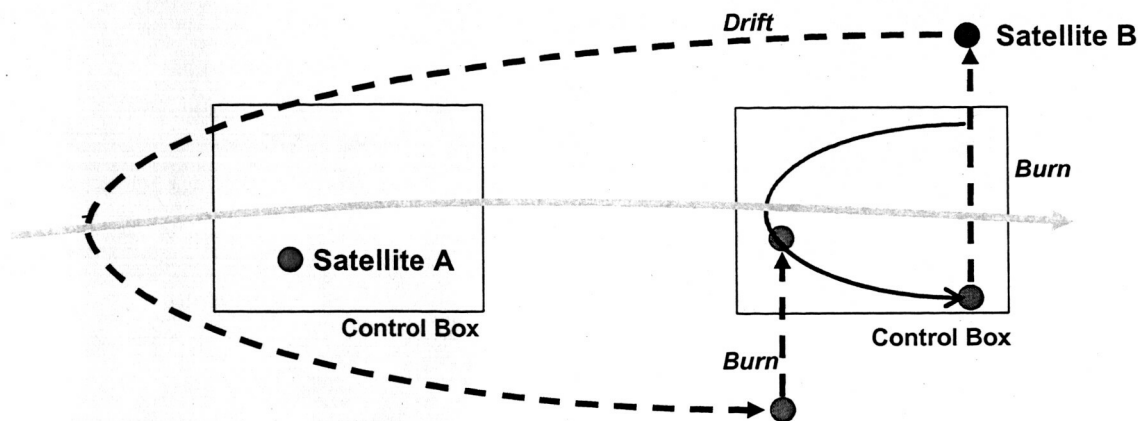


Figure 14 – Drag Makeup Maneuver Too Large
(No Retrograde maneuver capability available)

Approved Control Box Violations

For efficient operations, a satellite may find it advantageous to leave its Control Box for a short period (i.e., a few days). Planned Control Box excursions (Figure 15) can be submitted for approval to the Constellation Manager and the MOWG if and only if the following conditions are satisfied:

- The satellite retains full capability to perform propulsive maneuvers
- The excursion shall not endanger any other satellite; in particular, the planned excursion shall not go past *the halfway point into the buffer zone between it and the nearest satellite*
- The excursion provides advantages to the satellite's operations
- The excursion shall not dramatically impact correlated science observations with any other AC (unless approval was received from that science team)
- Notice is provided to all AC teams at least 5 days prior to the Control Box violation.

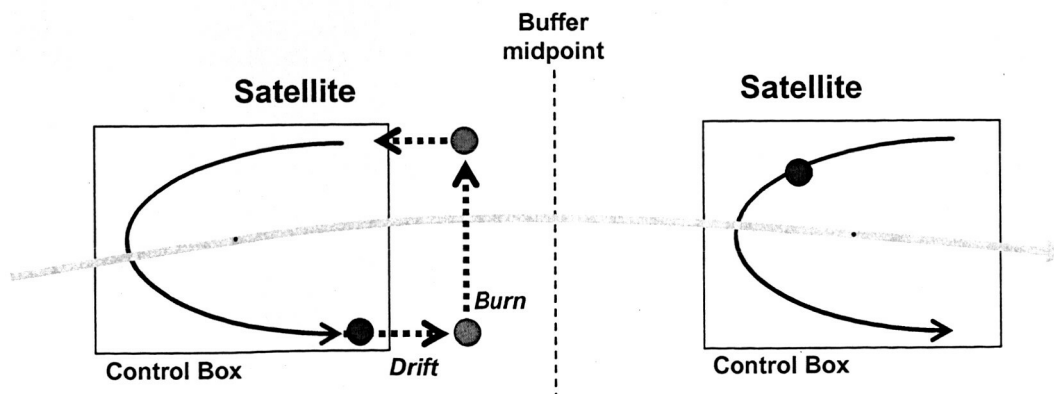


Figure 15 – Satellite B Executing a Planned Control Box Excursion

Once a satellite team has received concurrence that its satellite, Satellite B in Figure 15, is allowed to leave its own Control Box on an anticipated excursion, the standard procedure for performing drag makeup maneuvers will be followed. The CCS will continue the automated control box and ZOE violation automated calculations during the excursion period and will notify the satellite team and the Constellation Manager until the satellite has returned to its box.

A Missed Maneuver during a CALIPSO/CloudSat Coordinated Drag Make-Up Maneuver

To satisfy their formation flying requirements, CALIPSO and CloudSat coordinate their drag make-up maneuvers and execute them almost concurrently. Coordination details are contained in the CALIPSO/CloudSat ICD. A CALIPSO drag make-up maneuver consists of two burns separated by approximately one and a half orbits. The first burn is always planned to be outside ground station contact, although this is not a requirement. An S-Band ground contact will occur one orbit after the second burn. Maneuver notification will be available at this time via email and fax. One orbit later, a second ground contact is scheduled. After this pass, the updated ephemeris will be available for distribution to CCS and to CloudSat.

If CALIPSO fails to execute either of its planned burns in its drag make-up maneuver and CloudSat executes its maneuver as planned, CloudSat will be on a post-maneuver trajectory relative to CALIPSO that will result in an undesired close approach, typically in two days, unless CloudSat promptly executes an "undo" maneuver. An undo maneuver cancels the effect of CloudSat's drag make-up maneuver arresting its motion toward CALIPSO and preventing a close approach between CloudSat and CALIPSO.

If CloudSat fails to execute its corresponding drag make-up maneuver, it will break formation with CALIPSO, but will not immediately endanger CALIPSO or any other Constellation satellite. Table 2 is a high-level timeline of the coordination expected for this scenario.

Table 2: CloudSat and CALIPSO Coordination

Activity	Minutes	Hours
Operational Coordination Group telecon*	<Tuesday prior to Burn 1>	
CALIPSO Burn 1	0	0.0
CloudSat Burn	<Between CALIPSO Burn 1 and Burn 2>	
CALIPSO Burn 2	150	2.5
CALIPSO ground contact	250	4.2
Notification of success or failure to CloudSat by email and FAX	260	4.3
Operational Coordination Group telecon*	265	4.4
CALIPSO ground contact 2	350	5.8
CALIPSO Orbit products to CloudSat	410	6.8
CS Undo Automatic Burn**	<Approx. 12 hours after CloudSat Burn>	

* Members of Constellation management and operations teams

** Cancelled if the CALIPSO maneuver executes as planned

CloudSat or CALIPSO Falling into a Safe-Hold during Ascent Phase

The CloudSat and CALIPSO ascent plans are "independent, but coordinated". They were designed for minimal interaction between the two mission teams under nominal conditions. If either satellite falls into safehold during early orbit operations prior to entering the AC, the other satellite team plans to proceed with its own ascent plan and join the constellation according to its original schedule. While the complexity of the possible scenarios involving the ascents is not addressed in this paper, the general plan is discussed below.

- If CloudSat falls into Safe-hold, the CALIPSO team plans to perform its ascent maneuvers according to schedule and place its satellite in its Control Box.
- If CALIPSO falls into Safe-hold, the CloudSat team plans to perform its ascent maneuvers according to schedule and enter the AC. It will not be able to fly in formation until CALIPSO joins the constellation. Under these circumstances, CloudSat would take up a position 20 seconds along-track behind Aqua's Control Box and would basically station keep at that this position until CALIPSO succeeded in achieving its box. If CALIPSO cannot reach its Control Box, the CloudSat team will need to recommend their planned approach for flying the constellation without CALIPSO.

Predicted Close Approach with Space Debris

The possibility of collision with space debris is increasing all the time. A collision could disable an AC satellite and the resulting debris field could threaten all member satellites. AC satellites need to be prepared to perform evasive maneuvers if a credible risk of collision is identified. The process and procedures for handling this type of contingency are still in the development stage; the information below summarizes the activities to date.

The NASA ESMO Office has taken the lead role in researching the options available to predict close approaches with space debris. This has developed as a joint effort with the United States STRATegic COMmand (USSTRATCOM) operated by the U.S. Air Force (USAF). Routine monitoring has already begun for the on-orbit missions, with USSTRATCOM providing close approach predictions on a periodic basis to the ESMO Office. The CloudSat mission team plans to use the debris avoidance predictions available from the USAF through Kirtland Air Force Base, where the CloudSat Control Center resides.

Predicted close approaches are typically identified several days in advance, but these initial predictions do not have the precision needed to make evasive maneuver decisions. As the date of the predicted close approach nears, the precision usually increases and mission teams can make decisions about evasive maneuvers.

CCS Unavailable For an Extended Period

If CCS is unavailable for more than a few days, there are two impacts:

- Alternate measures must be taken to ensure that constellation satellites are safe from close approaches
- Backup means must be applied to transfer and convert Constellation data products.

Each satellite team knows whether their satellite is within its Control Box. As long as all satellites remain so, there is no short-term threat of a close approach. It is only during a predicted or actual Control Box excursion that a CCS substitute must be activated. Control box and close approach analysis can be performed manually by the satellite teams and/or by the ESMO Constellation team. Notifications will occur via manual e-mail and telephone. Product exchanges are expected to occur through manual processing by each satellite team using ftp or e-mail to transfer the data.

SUMMARY

To reduce the possibility of constellation-wide contingency situations which could affect all the Afternoon Constellation satellites, general contingency procedures have been developed, based on the most likely and most constellation-impacting scenarios defined by the AC group. The described procedures provide general guidelines for the process of successful resolution of the contingencies. Further analysis is needed for contingencies related to debris avoidance as well AC contingencies which could impact the Earth Science Morning Constellation.

ACKNOWLEDGEMENTS

This work was done as part of the Afternoon Constellation Mission Working Group.

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